CTVS®
Multilayer Varistors for Automotive

Automotive E series
for ESD and transient protection

EPCOS AG
A TDK Group Company
Piezo & Protection Devices Business Group • Multilayer Technology
Munich, Germany
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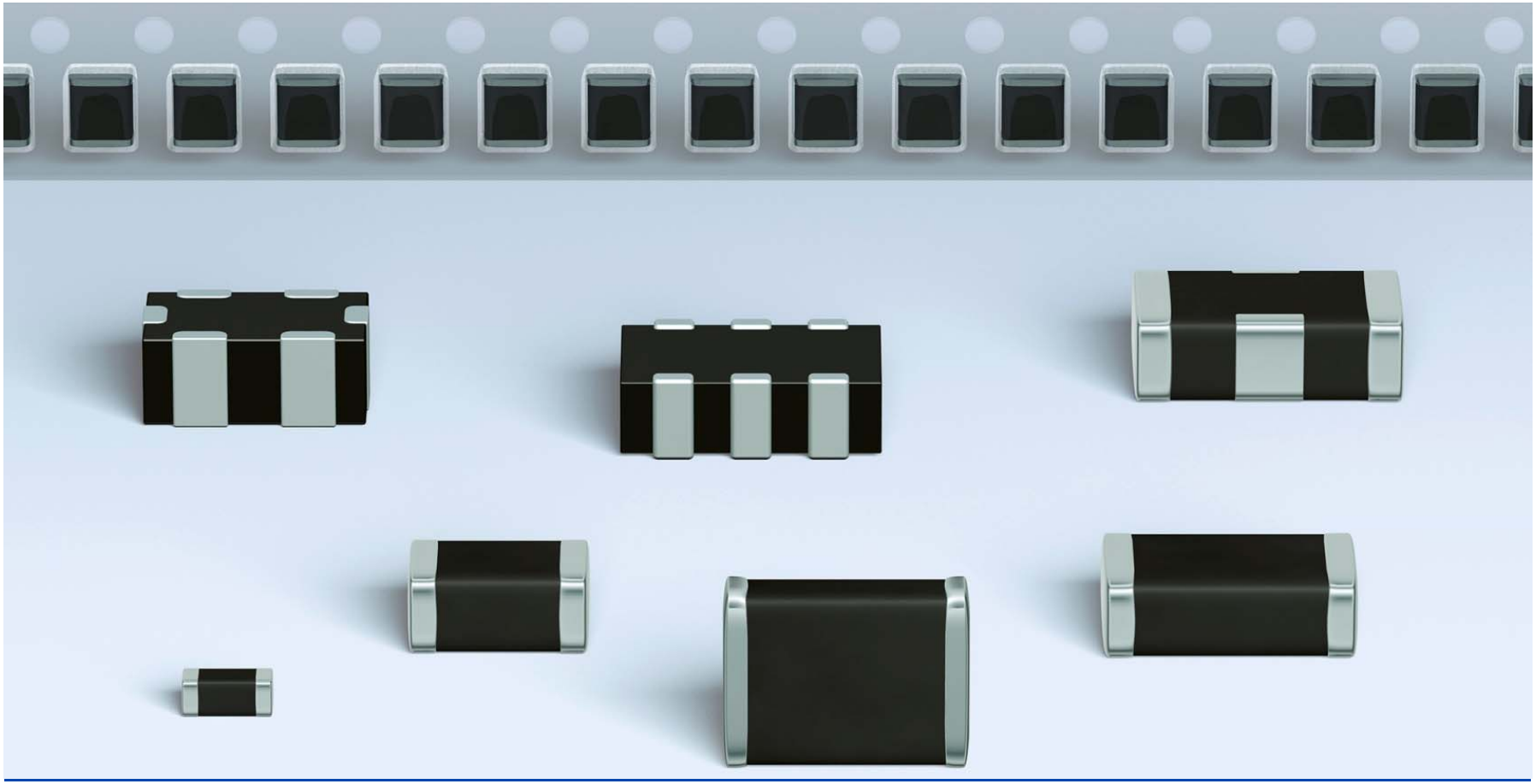
CTVS* multilayer varistors: Contents

***** **C**eramic **T**ransient **V**oltage **S**uppressors

CTVS multilayer varistors: Product range

EPCOS CTVS (**C**eramic **T**ransient **V**oltage **S**uppressors) components feature excellent characteristics for a wide range of applications.
ESD (**E**lectro **S**tatic **D**ischarge) and surge pulse protection is the key functionality.



CTVS multilayer varistors: just everywhere…

- High data rates for wireless communications
- High system integration in applications sensitive to ESD
- High safety and reliability, especially for automotive
- Reliable surge protection for telecom and industrial devices

ESD protection of
phones, tablets & LEDs
Case size EIA 01005 … 0402

ESD/EMI protection
of automotive ECUs
Case size EIA 01005 … 2220

Surge protection of
telecom & industrial
Case size EIA 1812 … 2220

CTVS multilayer varistors: Application fields

Automotive

Data bus systems	Infotainment	Safety	Body and comfort	Battery
CAN bus, LIN, MOST	Mobile phone modules	Airbags	Air-conditioning	Load dump/ jump-start protection
Ethernet, FlexRay	Navigation	ABS/ ESP	Lighting (LED)	Battery control units
	Audio systems		Diagnostic systems	
			Electrical drives (e.g. wipers, windows)	

The range of CTVS components suitable for automotive applications includes the product series multilayer varistors (automotive E series) and leaded transient voltage/ RFI suppressors (SHCV series).

- ESD protection according to ISO 10605/ IEC 61000-4-2
- Load dump, jump start capability
- Reliability based on AEC-Q200, Rev. D

Communication

Mobile applications	Base stations	Interfaces	Reception tuners
Smartphones, PDAs	Secondary surge protection	I/O and power keys	TV, radio, DAB, DVBT
Tablet PCs		Chargers, USB, HDMI	GPS, satellite radio

Due to their small size and high robustness, multilayer varistors, ESD/EMI filters and CeraDiode®s are being used e.g. for ESD protection in mobile devices.

- ESD protection to IEC 61000-4-2, level 4
- Ultra-low DC leakage current
- Low device capacitance

Industrial

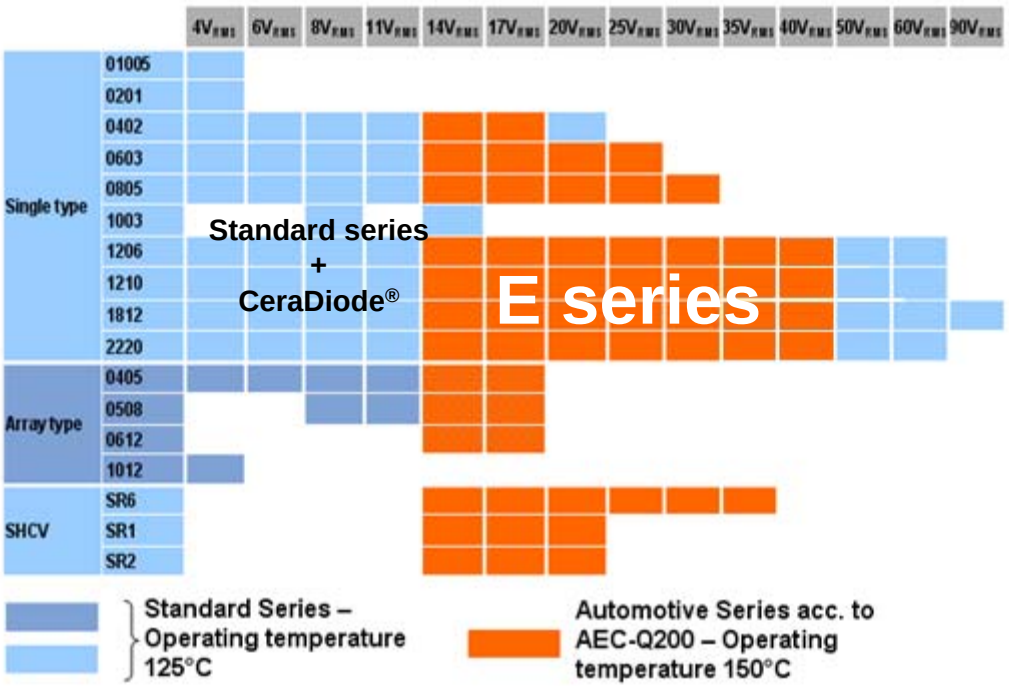
Lighting	Building applications	Automation	Medical
LED lighting	Smoke and fire detectors	Communication interfaces (e.g. USB 2.0, CAN bus, Ethernet)	Hearing aids
	Control and security systems	Serial bus interfaces (e.g. RS-232)	Blood glucose meter
		Human interfaces (e.g. buttons, touchpads, PS/2)	
		Power supply units	

Industrial electronics are sensitive to transients caused by both ESD and overvoltage. ESD can be caused by the human body (e.g. during handling stages) but also by the machine itself. Typical overvoltage transients are surge, burst, cable discharges and so-called electrical fast transients (EFT) often caused by switching of inductive loads.

CTVS multilayer varistors: Portfolio

Shapes 150 °C

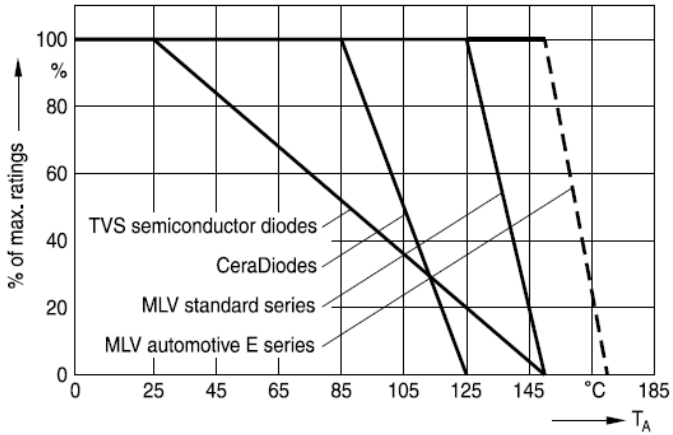
Single types | Array types | SHCV types



Features

- Case sizes EIA 0402 … 2220 + SHCV
- Voltage range 14 … 60V
- Qualification according to AEC-Q200 (E series)
- ESD protection acc. to IEC61000-4-2
- Specified load dump & jump start
- Low leakage current
- High operating temperature up to 150 °C
- No temperature derating up to 150 °C
- High mechanical robustness
- Nickel barrier termination for lead-free soldering
- ROHS-complaint and 100% Pb-free

Temperature derating

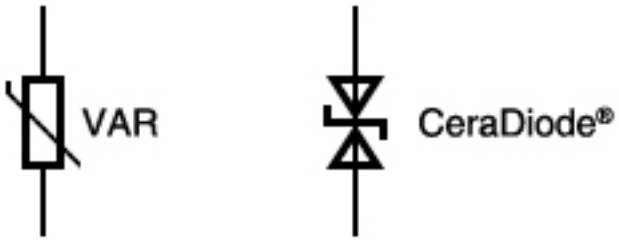


CTVS multilayer varistors: Functionality

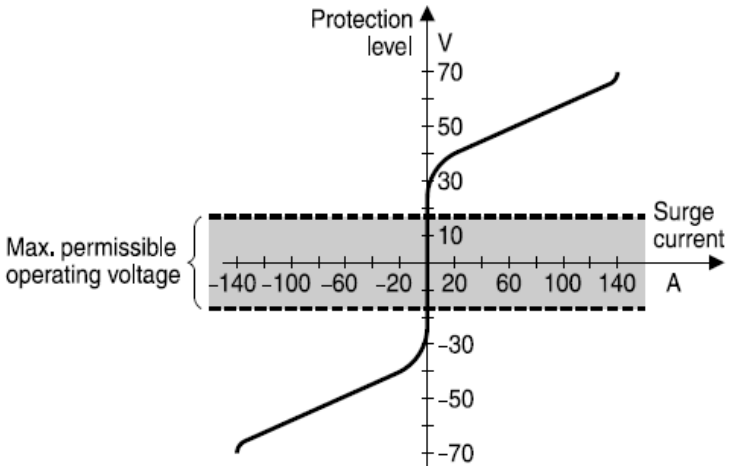
Multilayer varistors or so-called Ceramic Transient Voltage Suppressors (CTVS) are voltage-dependent resistors with a symmetrical V/I characteristic curve whose resistance decreases with increasing voltage.

Because of their application as overvoltage protection devices, they are also often referred to as TVS (Transient Voltage Suppressors) on silicon basis. Connected in parallel with the electronic device or circuit that is to be guarded, CTVS threshold value and thus prevent any further rise in the transient overvoltage.

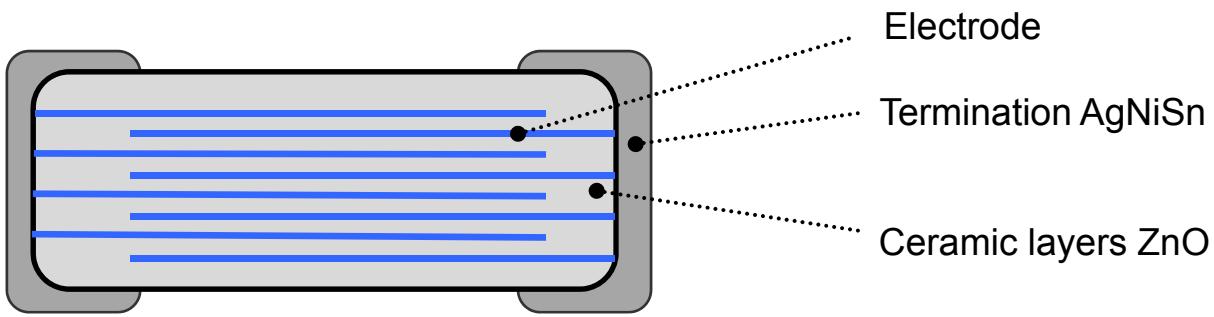
Circuit diagram symbol



Protection level (V/I characteristic curve)



CTVS multilayer varistors: Design

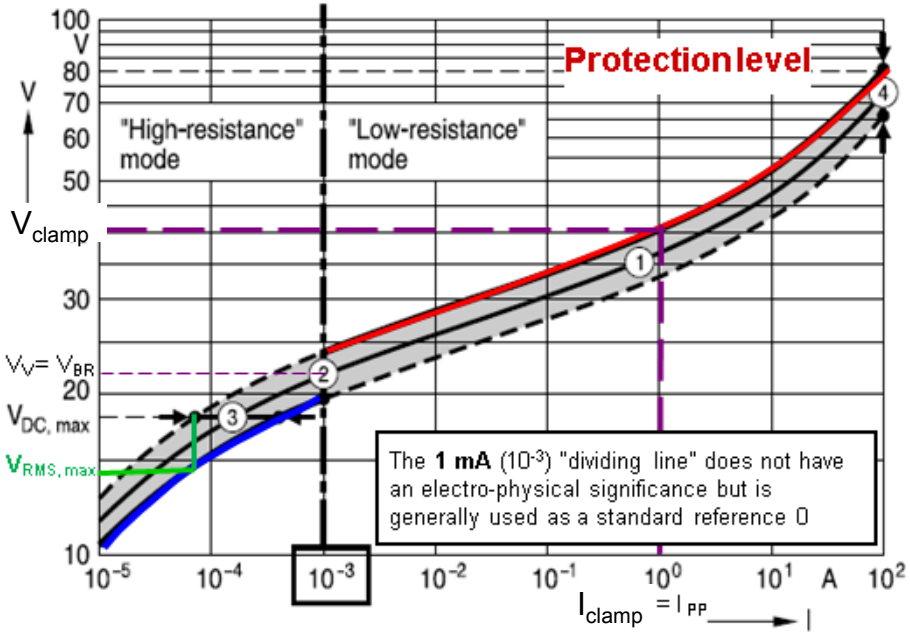


- The chip of a CTVS multilayer consists of a stack of alternating ceramic/ electrode layers. The thickness of the ceramic layers affects the protection level.
- In the active volume of the ceramic chip there are a number of internal electrode layers with an overlapping area affecting the pulse absorption capability. The internal electrodes are connected to the terminals or external electrodes.
- The nickel barrier termination is suitable for lead-free reflow soldering.

CTVS multilayer varistors: V/I characteristic curve

CTVS are operated in one of two modes. These modes concern two different segments of the CTVS V/I curve ① which lies within a well defined tolerance band ②:

- **“High-resistance” mode (<1 mA)**
  If the circuit is operated at normal operating voltage the CTVS has to be highly resistive. Here, the circuit designers may generally want to know about the largest possible leakage current at the given operating voltage. Therefore, the lower limit of the tolerance band is shown.
- **“Low-resistance” mode (>1 mA)**
  In an overvoltage event the CTVS has to be highly conductive. Here, the circuit designer’s primary concern is about the worst-case voltage drop across the CTVS. The upper limit of the tolerance band is shown. The clamping voltage V_{clamp} is the voltage across the CTVS in an overvoltage event.



Example

CT0805K14G (max. AC operating voltage of $V_{RMS, max}$ = 14 V and a varistor tolerance K of ±10%)

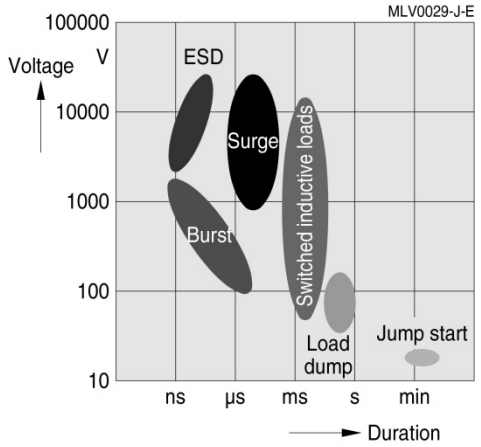
The CTVS V/I characteristic curve ① shows the mean value of the tolerance band between the limits indicated by dashed lines ②. The mean at 1 mA represents the varistor voltage ($V_V = V_{BR}$), in this case 22 V. The tolerance K ±10% refers to this value, so at this point the tolerance band ranges from 19.8 to 24.2 V (region ②). For the CT0805K14G MLV, a maximum permissible operating voltage of 18 V_{DC} is specified (③). Depending on the actual value of the MLV in the tolerance band, you can derive a leakage current between $6 \cdot 10^{-6}$ A and $2 \cdot 10^{-4}$ A at room temperature (region ③) as well as an increase of the voltage across the MLV to between 65 V and 80 V (region ④) assuming a surge current of 100 A.

CTVS multilayer varistors: Transient environment

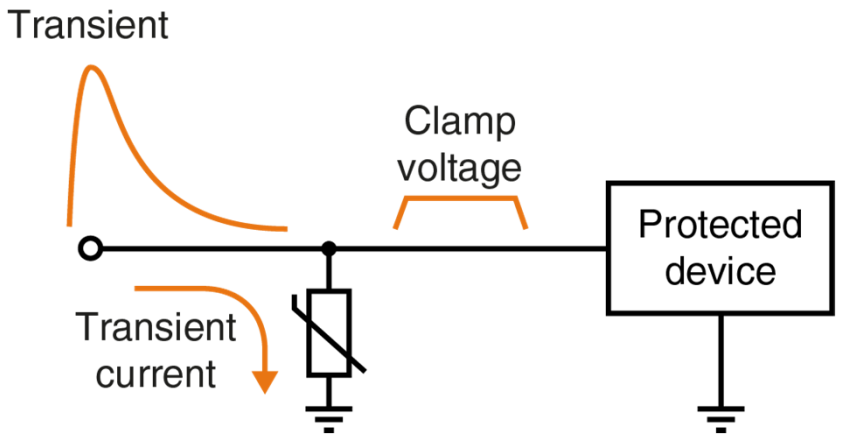
Common automotive transients and test standards

Phenomena	ESD	BURST/ EFT (electrical fast transients)	Surge	Surge	Load dump	Jump start
Cause	Electrostatic discharge	Switching processes	Lighting	Switching of inductive loads	Disconnected battery	Use case
Test voltage	up to 15 kV	up to 4 kV	up to 4 kV	up to 4 kV	up to 600 V	up to 36V
Test pulse duration	ns	ns (single pulse) µs (burst)	µs	ms	ms	s … min
Standard	IEC 61000-4-2	IEC 61000-4-4	IEC 61000-4-5	IEC 61000-4-5	ISO 16750-2	ISO 16750-2

Peak voltage/ pulse duration



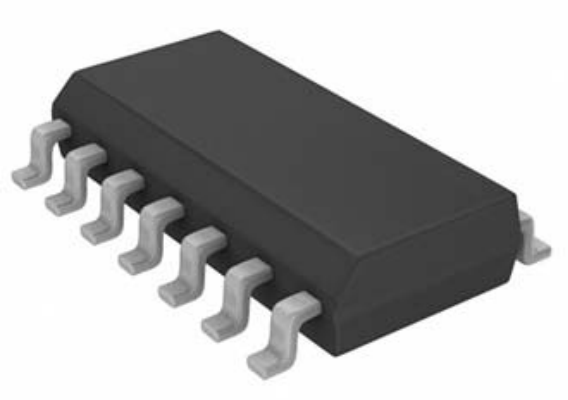
Protection principle



CTVS multilayer varistors: Package vs. TVS

CTVS multilayer varistor

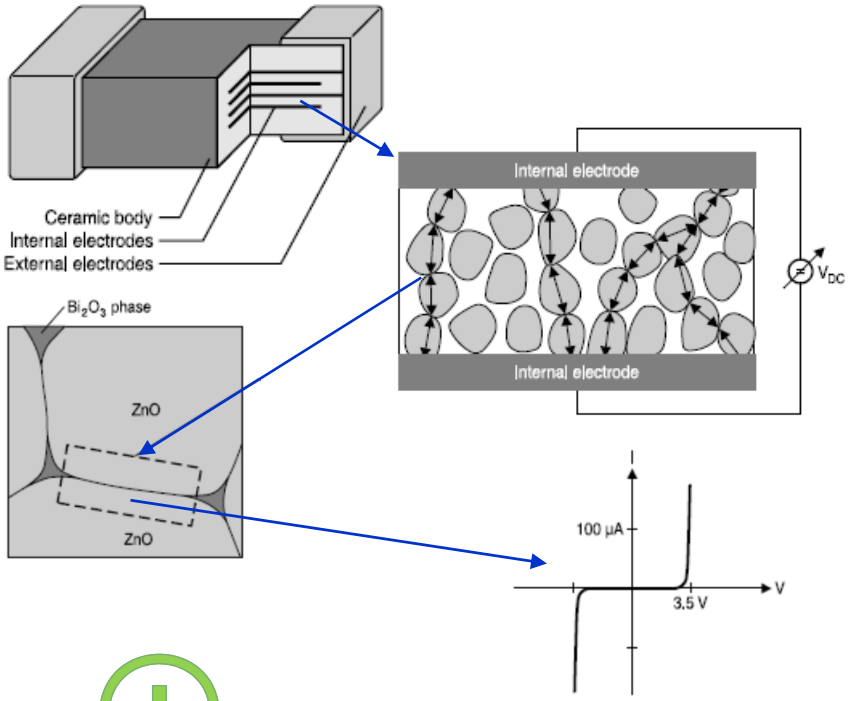
Semiconductor diode (TVS)

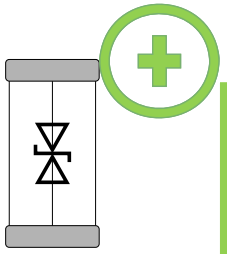


No leads on the component	Long leads on the component
➔ Low parasitic inductance	➔ Causes a high parasitic inductance
➔ No influence on clamping voltage	➔ Influences the clamping voltage level at very fast transients (e.g. first peak of an ESD spike)
➔ Less space consumption on PCB	➔ Higher space consumption on PCB

CTVS multilayer varistors: Construction vs. TVS

CTVS multilayer varistor

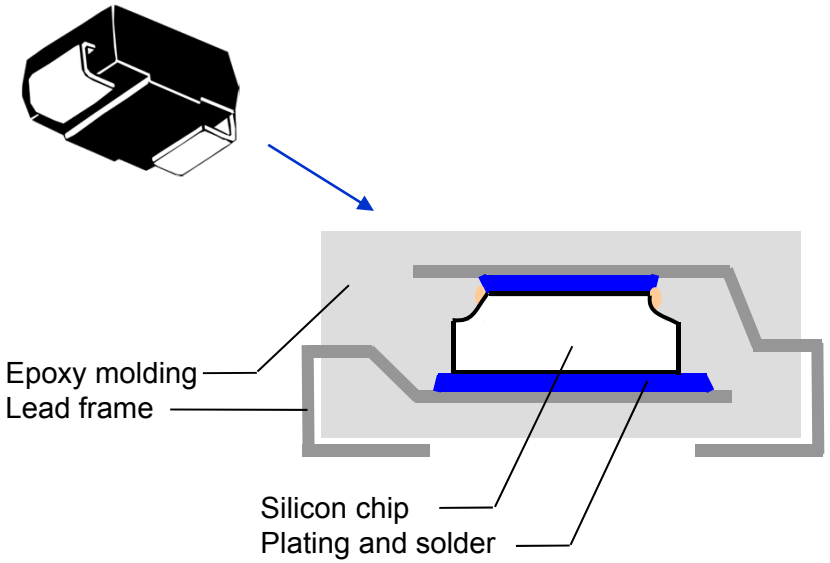


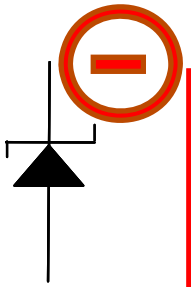


Millions of “P-N junctions”

Energy absorption takes place inside the ZnO grains and is provided nearly over the entire volume of the component.

Semiconductor diode (TVS)



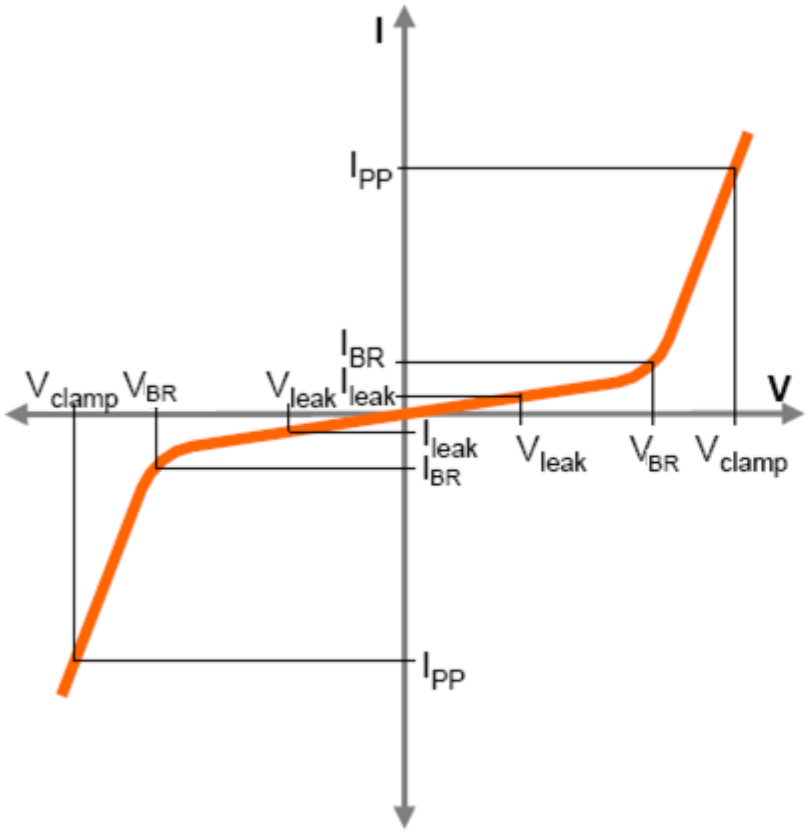


One “P-N junction”

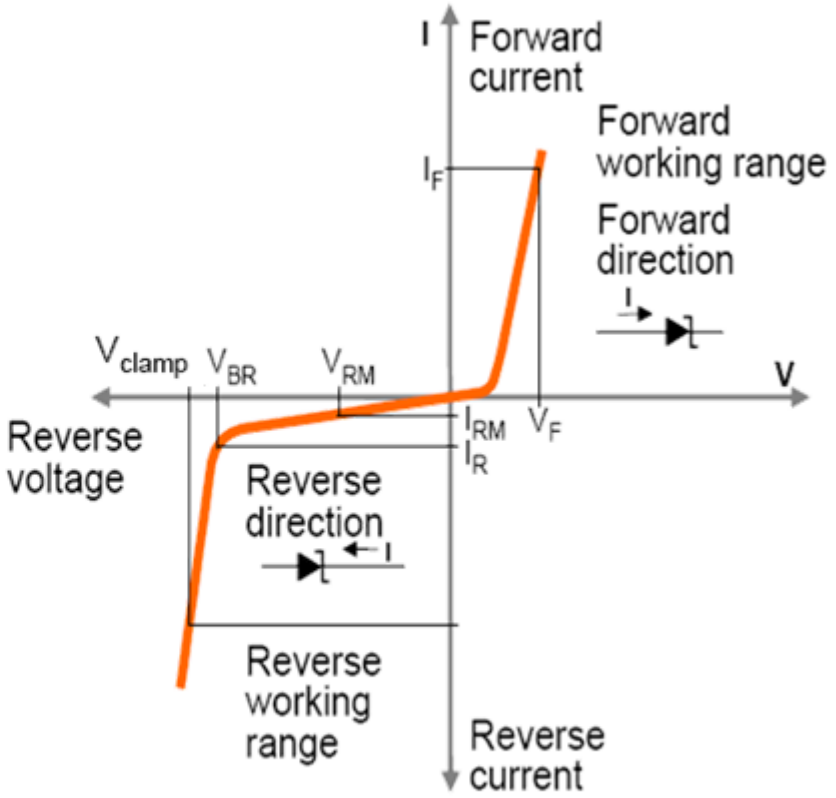
Energy absorption only in the relative small area of the pn junction possible.

CTVS multilayer varistors: V/I characteristics vs. TVS

CTVS multilayer varistor



Semiconductor diode (TVS)

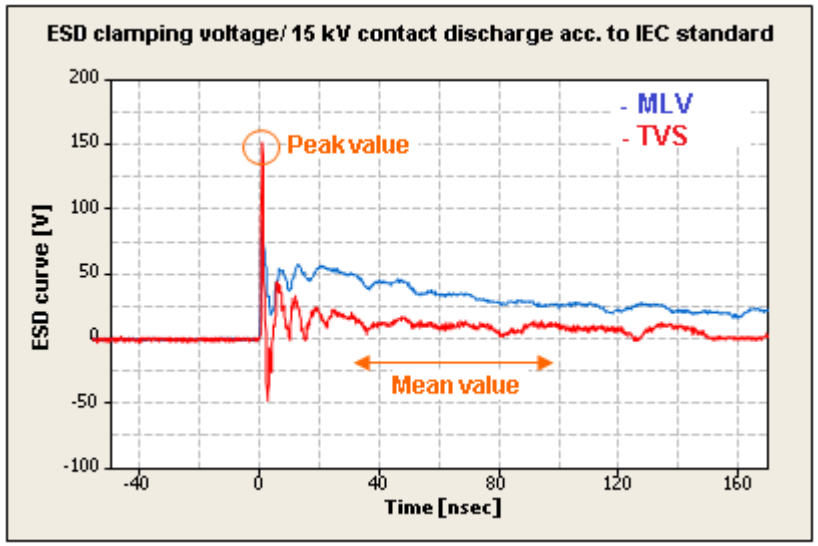


Bidirectional

Unidirectional

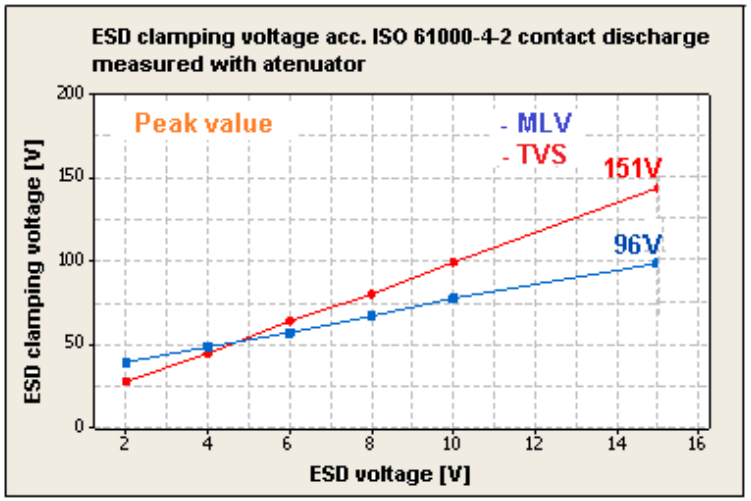
CTVS multilayer varistors: Clamping voltage vs. TVS

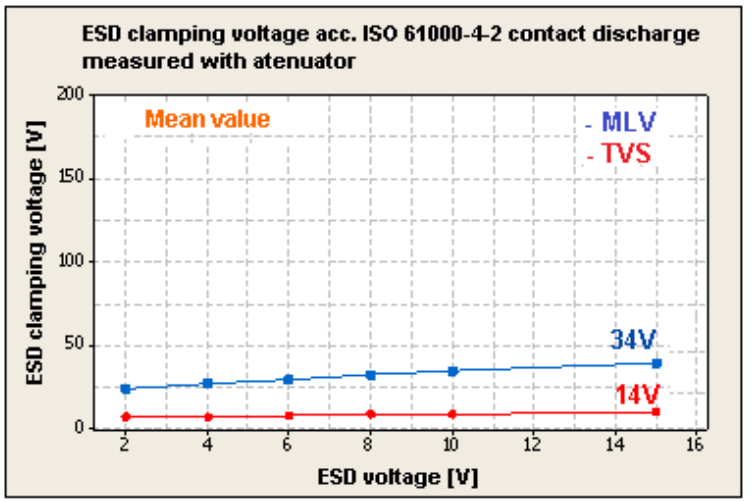
Tests acc. to IEC61000-4-2 method



Y: Mean value of the clamping voltage between 30 and 100 ns, calculated by $Y = \frac{\int_{30nsec}^{100nsec} x dt}{n}$

Multilayer varistors can significantly clamp the ESD peak pulse lower than TVS diodes, especially for high voltage >> 6 kV.



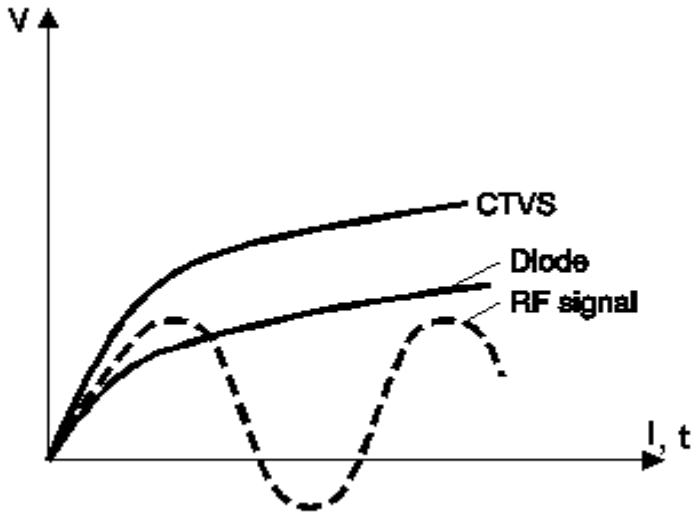


CTVS multilayer varistors: Signal integrity vs. TVS

CTVS multilayer varistor

CTVS MLVs have typically a higher clamping voltage

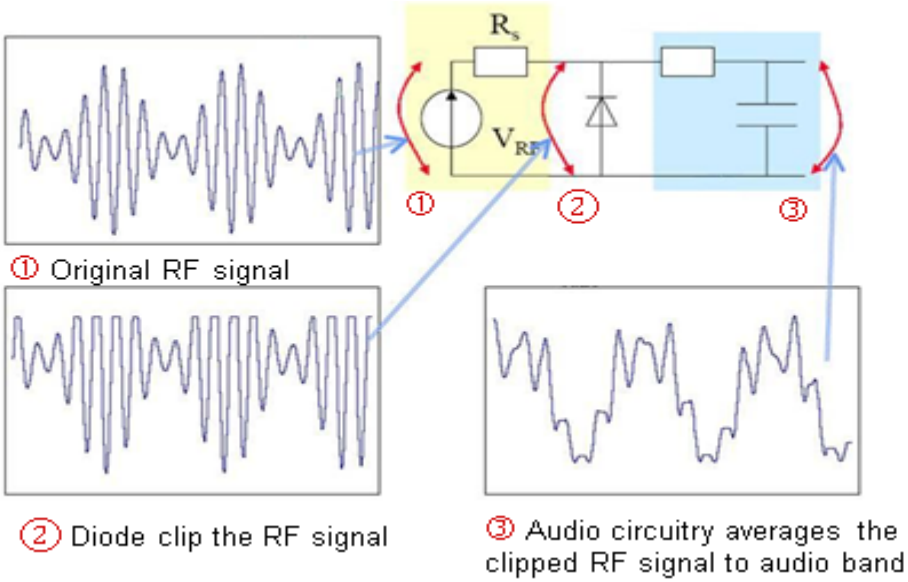
- ➔ The V/I curve is steep
- ➔ The V/I curve does not touch the RF signal
- ➔ No signal distortion



Semiconductor diode (TVS)

TVS have typically a lower clamping voltage

- ➔ The V/I curve is less steep
- ➔ The diode does clip the RF signal
- ➔ Error in signal transmission

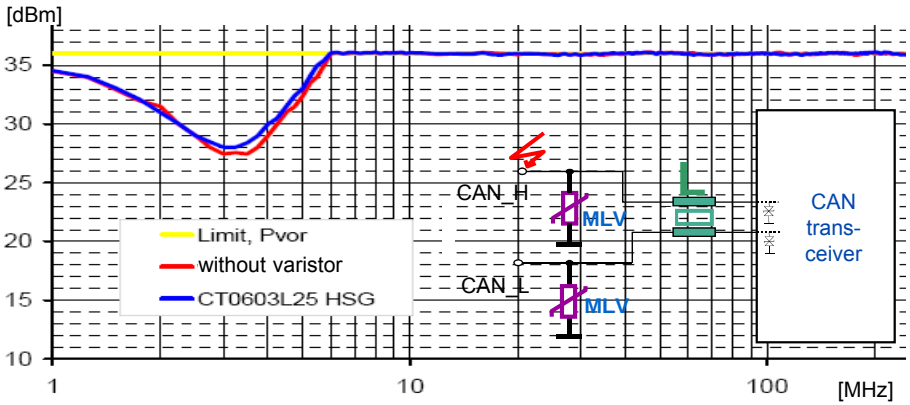


CTVS ML varistors offer a low non-linearity which leads to a higher signal integrity.

CTVS multilayer varistors: RF filtering vs. TVS

DPI method (Direct Power Injection): Continuous RF disturbance power (from 1 MHz to 1 GHz, yellow line) delivered by a generator is fed into a pin of a test board. By coupling out of interference power, a characterization of the immunity of the integrated circuit is possible. Due to impedance mismatch, most of the RF power delivered by the generator is reflected towards the source and only a small amount enters the PCB and IC under test (red line).

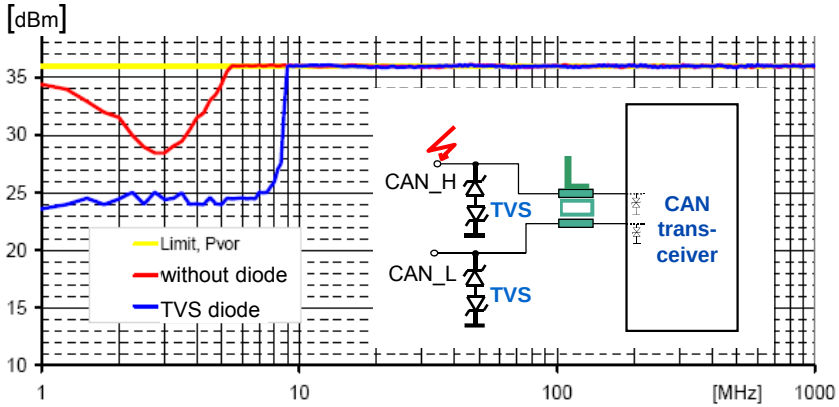
CTVS multilayer varistor



After putting a CTVS MLV on the PCB, the coupling out signal shows **no affect due to the varistor.**

The MLV have an excellent immunity to RF disturbances. MLVs are working like an EMC filter (Electro Magnetic Compatibility) **by using the internal capacitance for RFI suppression and RF filtering.**

Semiconductor diode (TVS)



After putting a TVS diode on the PCB, the coupling out signal is affected by the TVS.

The semiconductor diode has a bad immunity to RF disturbances.

CTVS ML varistors: Advantages vs. TVS diodes

- **Surge current handling capability**
  The interleaved electrode arrangement of multilayer ceramic devices allows surge currents of over 1 kA to be handled, whereas semiconductors can often withstand only a few amperes. This characteristic enables multilayer products to be used not only for protection against ESD, but also for dealing with surge loads of much higher energy levels to IEC 61000-4-5.

- **Bipolar characteristics**
  ESD can occur with any polarity, which poses no problems for multilayer ceramic products with their symmetrical protection characteristics, whereas two components are often required to achieve the required bipolar characteristic with semiconductor suppressor diodes.

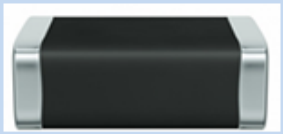
- **Operating temperatures**
  CTVS products can be subjected to full load at temperatures of up to 150 °C, whereas the load capacity of semiconductor suppressor diodes derates from temperatures of 25 °C upwards and is frequently reduced to 25% of the rated value at 125 °C.

- **EIA case size**
  The ceramic material for CTVS serves as an insulator on the exterior surfaces; the terminal electrodes are available as direct contact surfaces. By comparison, semiconductor components most times require a casing. This makes them correspondingly bulky and they require more mounting space.

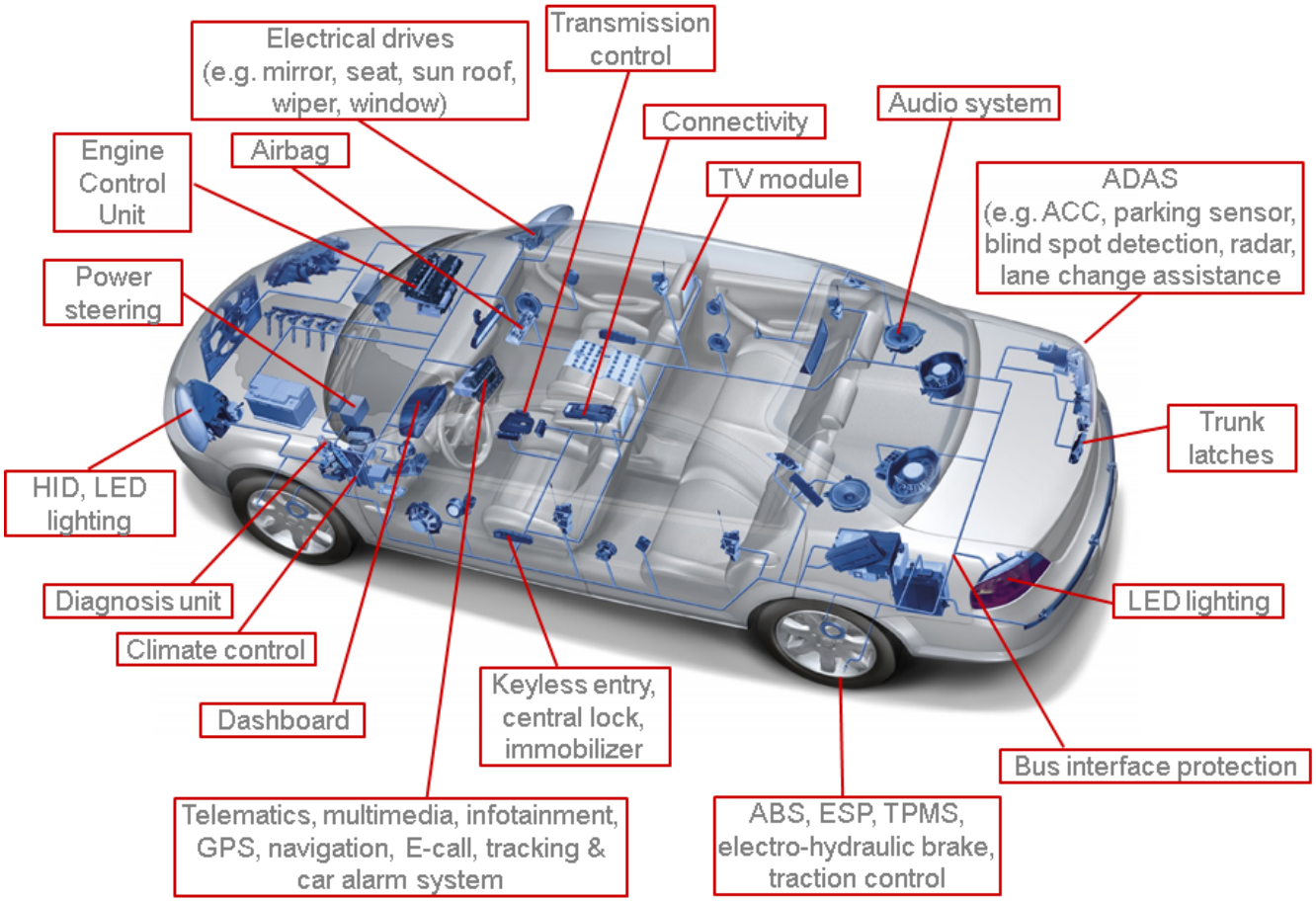
- **Response time**
  Due to their extremely low parasitic inductances, CTVS are fast enough to handle ESD pulses with very short rise times. One can find similar results for the die of the silicon used in semiconductor protective devices like suppressor diodes. However, when the die is mounted in its package, the response time often increases to values >1 ns due to the series inductance of its package.

CTVS multilayer varistors: Automotive E series

- No temperature derating up to 150 °C
- Very high life time robustness up to 150 °C
- Voltage range 14 … 40 V with low leakage current (typ. <1 µA)
- Reliable ESD protection up to 30 kV acc. to IEC 61000-4-2 (8 kV contact, 15 kV air)
- Broad product range with case size EIA 0402 … 2220
- 100% lead-free
- High electrical/ mechanical robustness over time
- Electrical characteristics are stable against repeated ESD (level 4 of IEC 61000-4-2), and high-energy transient pulses (jump start and load dump protection according to ISO 16750-2)
- Qualification based on AEC-Q200 and with extended stress tests

Automotive series		Application	Case size [EIA]	$V_{DC, max}$ [V]	Capacitance [pF]
E series		ESD protection for bus systems	0402 … 0805	14 … 40	10 … 10000
		Load dump & jump start protection	0805 … 2220	16 … 34	100 … 15000
ESD/ EMI filter array (2-fold MCV array)		EMI filtering & ESD protection	0508	12 … 16	10 … 100

CTVS ML varistors: Automotive E series applications



CTVS multilayer varistors for automotive applications are generally used for

- ESD protection (e.g. acc. to ISO 10605/ IEC 61000-4-2) for bus interfaces (e.g. CAN, LIN, MOST, Ethernet, FlexRay)
- Protection against high-energy transients (e.g. jump start and load dump protection) acc. to ISO 7637-2 and ISO 16750-2) occurring at e.g. battery lines.

CTVS ML varistors: E series application examples 1/3

Convenience

Top column module (TCM)

ESD protection for CAN bus interfaces

Type	Ordering code
CT0603K20G	B72500E0200K060
CT0603K25G	B72500E0250K060
CT0603K17LCG	B72500E2170K060
CT0603S20ACCG	B72500E5200S160

Convenience

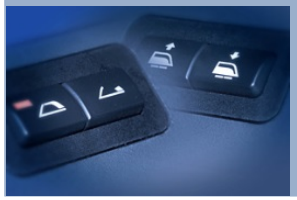
Body controller

ESD protection for CAN bus interfaces

Type	Ordering code
CT0603S17BCCG	B72500E5170S260
CT0603S20ACCG	B72500E5200S160
CT0603L25HSG	B72500E8250L060
CT0603K25G	B72500E0250K060

Convenience

Seat actuator and window lift



Protection against high-energy transients (inductive loads)

Type	Ordering code
CT1210S14BAUTOG	B72530E1140S262

CTVS ML varistors: E series application examples 2/3

Convenience

Infotainment

ESD protection for CAN bus interfaces and protection against high-energy transients (battery lines)

Type	Ordering code
CT0603V150RFG	B72500E7151V060
CT2220S14BAUTOE2G2	B72540E3140S272

Convenience

Rain & light sensor

ESD protection for CAN bus interfaces

Type	Ordering code
CT0402L14G	B72590E0140L060
CT0402S14AHSG	B72590E8140S160

Powertrain

Engine control unit

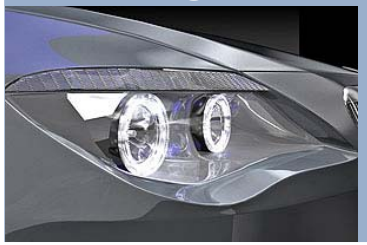
ESD protection for CAN bus interfaces and protection against high-energy transients (battery lines)

Type	Ordering code
CT0603L25HSG	B72500E8250L060
CT2220S14BAUTOE2G2	B72540E3140S272

CTVS ML varistors: E series application examples 3/3

Safety

Headlight



ESD protection for CAN bus interfaces

Type	Ordering code
CT0603K20G	B72500E0200K060
CT0603K25G	B72500E0250K060
CT0603S20ACCG	B72500E5200S160

Safety

Airbag

ESD protection for CAN bus interfaces & protection ag. high-energy transients (inductive loads & battery lines)

Type	Ordering code
CT0603L25HSG	B72500E8250L060
CT0805K25G	B72510E0250K062
CT1210K20AUTOG	B72530E1200K062

Safety

Parking assistance

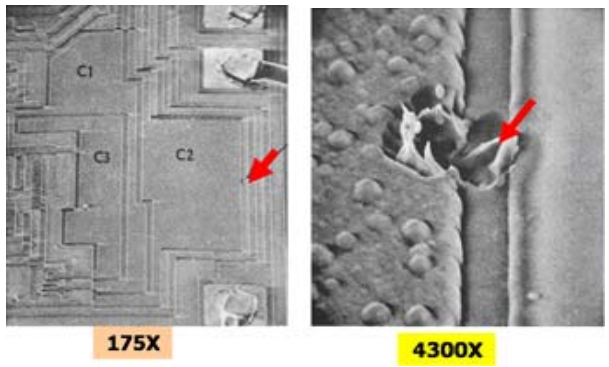
ESD protection for CAN bus interfaces & protection against high-energy transients (inductive loads)

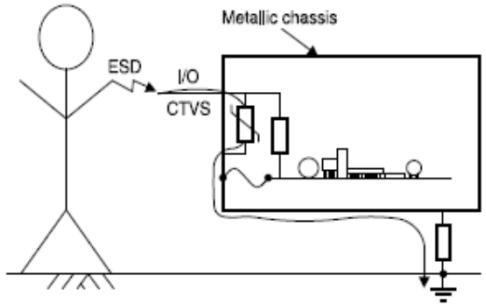
Type	Ordering code
CT0603K17LCG	B72500E2170K060
CT0805S14BAUTOG	B72510E1140S262
CT1210K20AUTOG	B72530E1200K062

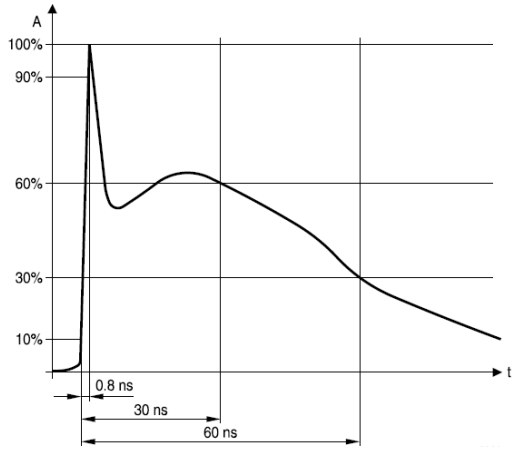
Varistors: ESD protection for bus interfaces - basics

Electrostatic discharge (ESD) are fast and high voltage transients. ESD transients are frequently caused by touching a device or contact with the fingers. More than 15 kV can be charged in a human body, thus a protection device for ESD requires high voltage withstand and very short response time.

Micro destruction caused by ESD pulses	Human body model to simulate ESD events	ESD discharge current to IEC 61000-4-2



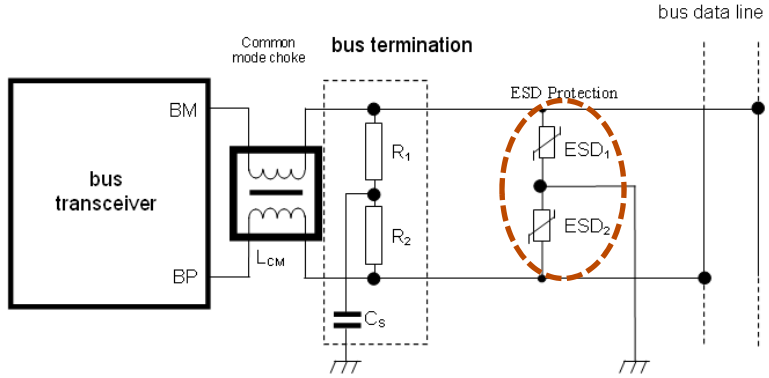




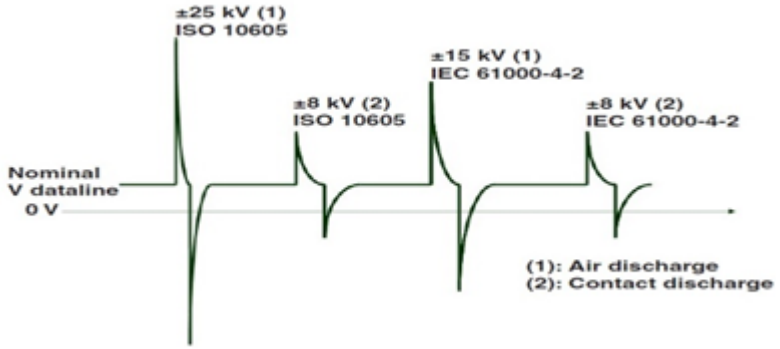
EPCOS CTVS multilayer varistors E series for automotive provide highly reliable ESD protection up to 30 kV according to IEC 61000-4-2, level 4 (8 kV contact, 15 kV air). The response time is <0.5 ns.

Varistors: ESD protection for bus interfaces/ data lines

ESD protection of bus interfaces/ data line



ESD pulses (acc. to IEC 61000-4-2/ ISO 10605)



Key product data

- No temperature derating up to 150 °C
- High life time robustness up to 150 °C
- Low clamping voltage
- Low leakage current <1 µA
- Reliable ESD protection up to 15 kV air discharge acc. to IEC 61000-4-2
- Bidirectional protection
- Stable protection level
- 100% lead-free
- Low parasitic inductance
- Extremely fast response time <0.5 ns
- Qualification based on AEC-Q200 with extended stress tests
- PSpice simulation models available
- Test board available

Product overview

CTVS series	Bus system	Benefit
E series	LIN CAN B	Ideal cost-effective solution for low-speed buses.
High-speed series	CAN C	No signal distortion on high-speed data lines.
ESD/ EMI filter array (2-fold MCV array)	FlexRay Ethernet	Protection of 2 lines with one component. Combination of EMI filtering and ESD protection.

CTVS MLV for ESD protection: Selection guide

CVS multilayer varistors E series for automotive for different data rates: From 20 kbit/s to 100 Mbit/s

CTVS E series for automotive		Size	LIN	CAN A/B	CAN C	FlexRay	MOST	Ethernet
Type	**Ordering code**	EIA	20 kbit/s	100 kbit/s	1 Mbit/s	10 Mbit/s	50 Mbit/s	100 Mbit/s
CT0402S17AG	B72590E0170S160	0402	X	X	X			
CT0402S14AHSG	B72590E8140S160	0402	X	X	X	X	X	X
CT0603K25G	B72500E0250K060	0603	X	X				
CT0603K17LCG	B72500E2170K060	0603	X	X	X		X	
CT0603S17BCCG	B72500E5170S260	0603	X	X				
CT0603S17ALCG	B72500E2170S160	0603	X	X				
CT0603K14G	B72500E0140K060	0603	X	X				
CT0603S14AHSG	B72500E8140S160	0603	X	X	X	X	X	X
CT0603L25HSG	B72500E8250L060	0603	X	X	X	X	X	X
CT0805K17G	B72510E0170K062	0805	X	X				
CT0805K25G	B72510E0250K062	0805	X	X				

Protection against high-energy transients: Basics

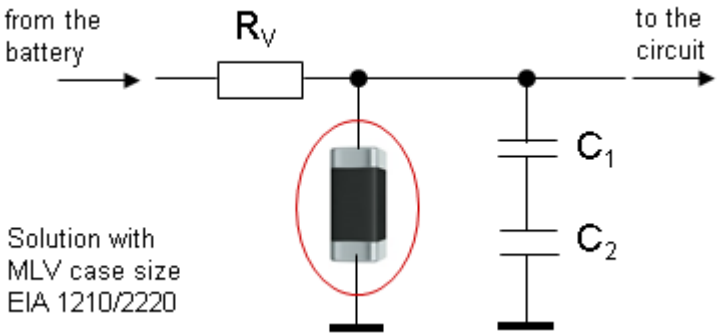
Transients are divided into several pulses

- **Transient voltages** in automotive supply lines occur due to disconnection of inductive load, sudden interruption of currents or switching processes. These transients may damage components connected to the supply lines. Typical automotive transients are defined in ISO 7637-2.
- **Load dump** in automotive electronics refers to a sudden disconnection of the vehicle battery from the alternator while the battery is being charged (e.g. break of a battery cable). Other loads connected to the alternator will be exposed to a high voltage surge (transient voltage) in the power line in case of such a disconnection of the battery. A load dump represents the most severe transient voltage in a vehicle. It is defined in ISO 16750-2.
- **Jump start** is a method of starting a vehicle with an external starter battery. If the external battery exceeds the voltage rating of the vehicle system, the electronic components must withstand this higher jump start voltage to avoid damage. Automotive specifications often require a 24 V jump start capability for 12 V systems.

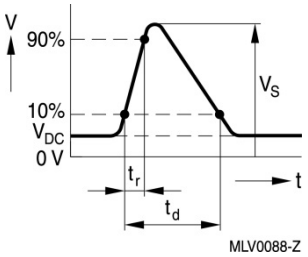
Our CTVS multilayer varistors E series for automotive provide highly reliable transient suppression according to ISO 7637-2 and ISO 16750-2.

Protection against high-transients in automotive

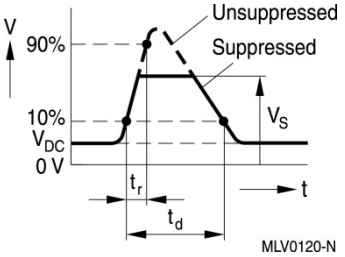
Central load dump protection



ISO 16750-2: Load dump pulse



Test pulse A



Test pulse B

Parameter	UA = 12 V	UA = 24 V	
Us (V)	79 to 101	151 to 202	**Minimum test requirement 5 pulses at intervals of 1 min.**
Ri (Ohm)	0.5 to 4	1 to 8	
td (ms)	40 to 400	100 to 350	
tr (ms)	10 / +0 / -5	10 / +0 / -5	

Key product data

- No temperature derating up to 150 °C
- High life time robustness up to 150 °C
- Low clamping voltage
- Low leakage current <1 µA
- Reliable ESD protection up to 15 kV air discharge acc. to IEC 61000-4-2
- Bidirectional protection
- Stable protection level
- 100% lead-free
- Low parasitic inductance
- Extremely fast response time <0.5 ns
- Qualification based on AEC-Q200 with extended stress tests
- PSpice simulation models available

Product overview

Type	Ordering code	EIA
CT0805K25AUTOG	B72510E1250K062	0805
CT1210S14BAUTOG	B72530E1140S262	1210
CT1210K25AUTOG	B72530E1250K062	1210
CT2220S14BAUTOG	B72540E1140S262	2220
CT2220S14BAUTOE2G2	B72540E3140S272	2220
CT2220K30AUTOG	B72540E1300K062	2220
CT2220K30AUTOE2G2	B72540E3300K072	2220

Protection against transient pulses: Product range

Load dump transients occurs

- Cable corrosion
- Poor or loose connection
- Intentional disconnection with the engine running

Load dump specified in ISO 16750-2

A severe transient voltage, caused by disconnection of the vehicle battery from the alternator while the battery is being charged.

Test A* Pulse shape without centralized load dump suppression

Test B* Pulse shape with a centralized load dump suppression

* Previously known as test pulse 5a and 5b in ISO 7637-2, 2004

CTVS multilayer varistors E series for automotive against different transient pulses and load dump pulses up to 25 J.

CTVS E series automotive		Size	$V_{RMS}/V_{DC, max.}$	$I_{surge, max.}$	W_{max} [mJ]	W_{LD} [J]	$P_{diss, max.}$	V_{jump} [V]
		EIA	[V]	[8/20 µs]	[2 ms]	[10 pulses]	[mW]	[5 min]
CT0805K25AUTOG	B72510E1250K062	0805	25 / 31	80	300	1	5	29
CT1210S14BAUTOG	B72530E1140S262	1210	14 / 16	400	1600	3	10	24.5
CT1210K25AUTOG	B72530E1250K062	1210	25 / 31	300	1700	3	10	29
CT2220S14BAUTOG	B72540E1140S262	2220	14 / 16	1200	5800	12	30	24.5
CT2220S14BAUTOE2G2	B72540E3140S272	2220	14 / 16	1200	5800	25	30	24.5
CT2220K30AUTOG	B72540E1300K062	2220	30 / 34	1200	12000	12	30	45
CT2220K30AUTOE2G2	B72540E3300K072	2220	30 / 34	1200	12000	25	30	45

CTVS ML varistors for automotive: Design support

Product brief

- **Ceramic Transient Voltage Suppressors: Combined EMI filtering and ESD protection for high-speed bus systems**
  Ordering no. EPC:63005-7600

Sample kits

- **Ceramic Transient Voltage Suppressors: E Series of Multilayer Varistors for ESD and High-Energy Transient Protection in Automotive Applications**
  Ordering no. B72499A9999K099

Data book

- **CTVS - Ceramic Transient Voltage Suppressors**
  Ordering no. EPC:62023-7600

NEW

Application support

- PSpice libraries
- Data sheets
- Contact sheet to get further support by our technical experts

Annex

Multilayer varistors: Important terms

- **Operating voltage V_{op}**
  Specified by maximum AC and DC operating voltages. These figures should only be exceeded by transients. Our multilayer varistor automotive E series is rated to withstand excessive voltage (jump start) up to 5 minutes.

- **Varistor voltage V_V/V_{BR}**
  The varistor voltage is the voltage drop across the CTVS when a current of 1 mA is applied to the device. It has no particular electrophysical significance but is often used as a practical standard reference in specifying overvoltage protection components. The tolerance of the varistor voltage refers to 25 °C.

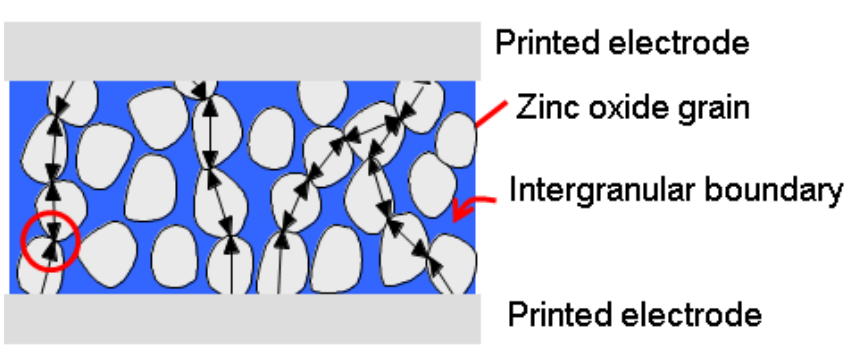
- **Protection level** (clamping voltage) **V_{clamp}**
  The protection level is the voltage drop across the CTVS for surge currents >1 mA. The V/I characteristics show the maximum protection level as a function of surge current (8/20 ms waveform).

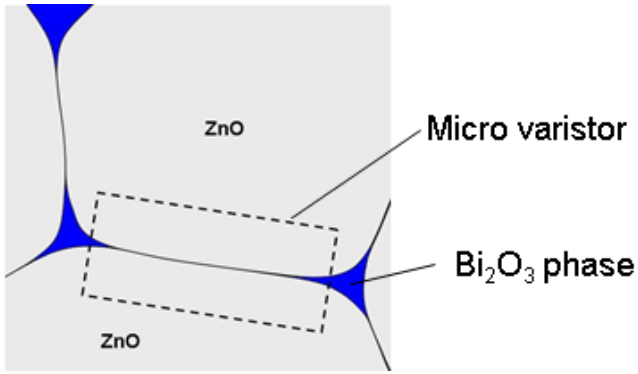
- **Maximum surge current $I_{surge, max.}$**
  The maximum non-repetitive surge current is usually defined by an 8/20 ms waveform (rise time 8 ms/ decay time to half value 20 ms) to IEC 62475.

- **Electrostatic discharge** (ESD)
  A rapid and short lasting surge of electric current that flows between two different objects when they come together and an excess of electric charge is transferred between them. At the component level there are three standards for passive electronic components: IEC 61000-4-2 level 4, AEC-Q200, Rev. D, ISO 10605 (2008).

- **Automotive high-energy transient pulses**
  The standards ISO 7637-2 and ISO 16750-2 detail EMC testing for automotive electrical systems, including test pulses 1, 2a/ 2b and 3a/ 3b (acc. to ISO 7637-2), and test pulses A and B according to ISO 16750-2, which simulate load dump. Load dump occurs when a battery is accidentally disconnected from the generator while the engine is running, e.g. because of a broken cable.

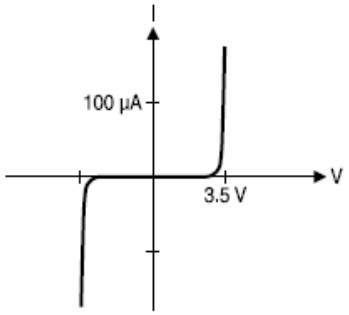
Multilayer varistors: Microstructure



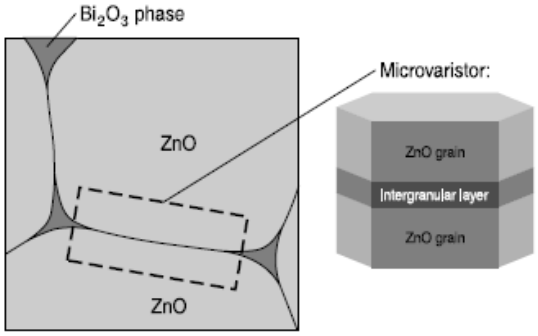


Sintering zinc oxide (ZnO) together with other metal oxide additives under specific conditions produces a polycrystalline ceramic whose grain boundary resistance exhibits a non-linear dependence on voltage. This phenomenon is called the **varistor effect**. At those points where zinc oxide grains are connected by an intergranular layer, sintering produces a microscopic structure of '**microvaristors'**. The electrical behavior of the CTVS multilayer results from the number of microvaristors connected in series or in parallel.

Varistor effect



Microvaristor



CTVS multilayer varistors: Product series at a glance

- **Multilayer varistors (MLV)** are components designed for circuit protection in automotive, industrial, communication and consumer electronics.

Standard	For general protection purpose
Automotive E series	AEC-Q200 qualified
Low clamping voltage	For sensitive IC protection
Surge protection	For high energies
High-speed	For data line protection

- **CeraDiode®s** are specific products for ESD protection of data, audio and video lines, analog and digital interfaces, ICs and I/O ports as alternative to semiconductor-based devices such as Zener and TVS diodes.

Standard	For general protection purpose
High-speed	For data line protection
LED	For protection of LED systems

- **ESD/EMI filters** present two functions in one component, ESD protection and EMI filtering. They protect audio lines (microphone and speaker) of a mobile phone from radio frequency noise generated by the phone itself.

- **Leaded transient voltage/ RFI suppressors (SHCV)** are leaded components consisting of a multilayer varistor and multilayer ceramic capacitor for combined protection against transients and RFI suppression in a single component.

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